

STATUS EVALUATION OF AMERICAN PIKA (*OCHOTONA PRINCEPS*) IN COLORADO

**COLORADO DIVISION OF WILDLIFE
DATA FOR USE BY USFWS 12-MONTH STATUS REVIEW**



Introduction

The American pika (*Ochotona princeps*) is the smallest member in the order Lagomorpha. The genus *Ochotona* is known from the late Miocene where they experienced their greatest diversity and widest distribution occupying a variety of habitats ranging from alpine to riparian communities across the Great Plains, Rocky Mountains, and Great Basin regions of North America (Wilson 1960; Vaughn 1986; Wilson and Reeder 1993). As the Wisconsin Glacial Episode ended and the hot and dry middle Holocene occurred, the American pika moved up in elevation to occupy mountainous areas in western North America (Grayson 2005). The reason for this upward shift in their range was likely driven by increases in average temperatures, decreases in moisture, and alterations in plant communities (Grayson 1993; Mead and Spaulding 1995 in Grayson 2005). Today, pika occur only in alpine and subalpine habitat and are considered a talus obligate species (Smith 1974; Hafner and Sullivan 1995; Beever et al. 2003; Grayson 2005).

On 1 October 2007 the American pika was petitioned to be listed under the Endangered Species Act (ESA) (Center for Biological Diversity 2007). The petition requested that a status review be completed on each subspecies of pika to determine if separate subspecies listing was warranted. Specifically, the petitioners requested that the five American pika subspecies inhabiting the Great Basin as well as the Lava-bed pika (*O. p. goldmani*) and Bighorn Mountain pika (*O. p. obscura*) be listed as endangered due to their small population sizes, isolation from source colonies, declining population trends, declining range extent, and the substantial long-term threat that global warming poses to their persistence. The petitioners requested that the remaining subspecies be listed as threatened.

Within Colorado, three separate subspecies are thought to occur: *Ochotona princeps figginsi* in the Elk and West Elk Mountains and the Park Range; *O.p. incana* in the Sangre de Cristo and Culebra Ranges, and the Spanish peaks; and *O.p. saxatilis* in the Front Range, Sawatch, and San Juan Mountains (Fitzgerald et al. 1994). However, Hafner and Sullivan (1995) demonstrated with allozymic studies on the American pika, that 4 major genetic units exist in the western United States (northern Rocky Mountain, Cascade Range, southern Rocky Mountain, and Sierra Nevada). Based on this information, the Integrated Taxonomic Information System (<http://www.itis.gov/>) recognizes 4-5 main groups for this species. Before a decision on the listing of the species occurs, clarification of the taxonomic uniqueness needs to be determined.

Concern about pika populations stem from recent, but limited research linking climate change to population extirpations in the Great Basin and Sierra Nevada Mountains (Beever et al. 2003, Moritz 2007). Changes in climate are thought to have affected pika distribution and population viability due to: 1) rising summer temperatures exceeding the thermal limits of the pika; 2) higher summer temperatures inhibiting normal foraging patterns resulting in the inability of pika to collect adequate forage for haystacks and to gain sufficient mass to overwinter; (3) lower snowfall totals reducing protective insulation for this non-hibernating species; (4) changes in temperature and precipitation that alter the composition and relative abundance of vegetation in and around talus; and (6) reductions in alpine permafrost that may lead to

degradation and eventual loss of talus habitats (Ray 2006; Center for Biological Diversity 2007).

On 7 May 2009, the U.S. Fish and Wildlife Service (USFWS) published a positive 90-day finding on the petition to list the pika under the ESA. The Federal Register document stated that the petitioners presented substantial information under Factor A, indicating that listing may be warranted due to the effects related to global climate change. A status review is to be completed for the species by February 2010. The USFWS is requesting information on the 1) historical and current status of the species; 2) population sizes and trends; 3) biology and ecology; 4) taxonomy and 5) ongoing conservation efforts for pika and their habitats. As part of this request, the Colorado Division of Wildlife (CDOW) is submitting the following information on persistence and extinction rates at historical pika sites, evaluation of the current status of the pika in the state, pilot study data for the initial development of a long-term monitoring protocol using occupancy modeling, an assessment of potential threats other than climate change that could be impacting pika populations, and a Predictive Range Model that evaluated land ownership patterns in pika habitat, assessed the extent of potential threats to the species, provided an estimate of potential habitat in the state, and furnished a sampling framework for site selection for long-term monitoring and conservation measures to be implemented.

Pika Habitat in Colorado

Pika in Colorado are described as occupying talus slopes situated in cool, moist habitats of the alpine tundra and subalpine forests at or above 3000 m (10,000 ft) (Fitzgerald et al. 1994). These habitats are extensive in Colorado (Figure. 1 *from* Hafner 1994) and may be one of the explanations for the widespread and abundant pika populations found to occur in the state. Beever et al. (2003) found that the amount of talus habitat was the strongest univariate predictor of pika population persistence. He also found that the maximum elevation of talus near pika sites predicted presence better than measured climate variables. The Colorado Rockies comprise a massive ecoregion dominated by high elevation subalpine and alpine habitats. Doesken et al. (2003) described the topography of Colorado as follows:

“With an average altitude of about 6,800 feet above sea level, Colorado is the highest contiguous State in the Union. Roughly three quarters of the Nation’s land above 10,000 feet altitude lies within its borders. The State has 59 mountains 14,000 feet or higher, and about 830 mountains between 11,000 and 14,000 feet in elevation. Colorado is known to contain more mountains at or above 4268 m (14,000 ft) than any other state”.

This expanse of high elevation, talus habitat in Colorado greatly exceeds that of the 2 study areas that have recorded pika declines or upward shifts in elevation ranges as listed in the petition. In addition, connectivity between these habitats appears to be sufficient to allow long-term persistence of populations due to the advantage of nearby source populations. Colorado pika populations therefore may be faring better than those where significant declines have been documented.

Figure 1. Distribution of pika based on patches of high-elevation vegetative zones copied from Hafner 1994.

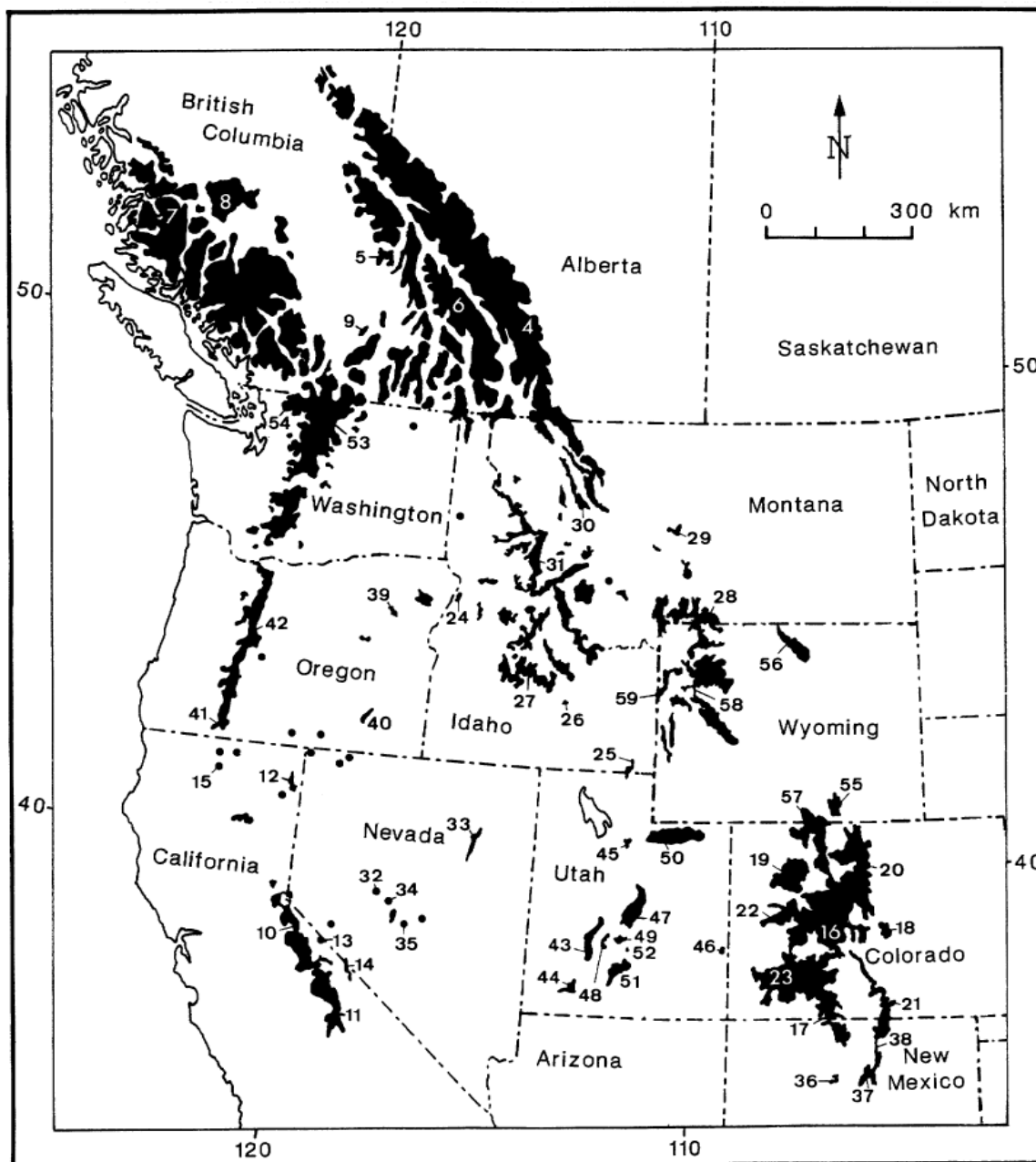


FIG. 1.—Distribution of *Ochotona princeps*, based on patches of high-elevation, vegetative zones (Farley, 1979; Küchler, 1970) inhabited by pikas. Numbers refer to sample sites in Appendix I.

CDOW 2008 Surveys

Though it has been argued that managing climate change is beyond the regulatory capabilities of CDOW, it remains important for the agency to monitor the impacts that it may have on wildlife. Current knowledge about climate change predicts that habitats and species composition will be altered due to changes in temperature and precipitation patterns. As this occurs, wildlife managers will be asked to deal with impacts associated with these changes. Pika, due to their sensitivity to climate and habitat changes, are a credible species to use as an indicator of alpine and subalpine ecosystem health over time. The development of baseline data and a long-term monitoring program for this sentinel species will aid CDOW in conserving and maintaining healthy ecosystems for Colorado's wildlife.

In 2008, the CDOW in cooperation with University of Colorado at Boulder (CU) conducted extensive statewide surveys to determine the persistence of pika at identified sites. Historical site surveys were designed to evaluate whether similar range contractions and local extinctions of pika populations, as documented in the Great Basin and Sierra Nevada Mountains, were occurring in Colorado. Other surveys were initiated to investigate current status of the species and for development of detection and monitoring protocols.

Objectives:

1. Evaluate historical and current status of pika populations:
 - a. Re-sample 'historical' sites where pikas were documented to occur prior to 1980 to evaluate persistence and extinction rates.
 - b. Locate new pika occurrence sites where surveys had not previously been conducted.
2. Use field collected data to develop a Predicted Range Model to aid in site-selection for a long-term monitoring program, assess potential habitat and connectivity of populations, and investigate potential threats to the species.
3. Evaluate the potential of using occupancy modeling to monitor pika populations.
4. Build collaboration between Universities, non-profit organizations, as well as the CDOW volunteer program to assist with future pika conservation work.
5. Develop a long-term, state-wide monitoring protocol for pika populations that will provide trend estimates with adequate precision for determining conservation efforts and evaluate changes occurring in the alpine and subalpine habitats with regards to anthropogenic disturbances and climate change.

Methods

Historical Sites:

To evaluate the status of the American pika in Colorado, CDOW coordinated with CU PhD candidate student Liesl Peterson and her 2 professors, Chris Ray and Robert Guralnick, to investigate persistence and extinction of pika at historical sites. Historical sites were identified by Liesl Peterson and were defined as those sites with documented pika occurrence prior to 1980 before anthropogenic climate change became prominent in many datasets (Intergovernmental Panel on Climate Change [IPCC] 2007). At historical sites selected for surveys, pika occupancy was evaluated and potential factors that could be affecting the distribution of pikas in the Southern Rocky Mountains in Colorado were examined.

To identify appropriate sites to survey, an initial list of 792 pika occurrence records within the Southern Rocky Mountain region was compiled using museum records (from GBIF data portal: <http://data.gbif.org>, Denver Museum of Natural History, and University of Colorado Museum), state checklists (Long 1965; Armstrong 1972; Findley et al. 1975), and numerous literature sources. The Southern Rocky Mountain Region was defined as the area from 41° 30' to 35° 20' N and -104° 54' to -108° 17' W and included portions of Wyoming and New Mexico as well as Colorado.

Locations for points were georeferenced following the guidelines of Chapman and Wieczorek (2006) and Guralnick et al. (2006). For each location, coordinates and an estimate of the error associated with those coordinates were calculated using Biogeomancer (<http://bg.berkeley.edu/latest/>) and additional topographic tools. These sites were ranked based on the error associated with the georeference, and sites with errors greater than 3000 m were eliminated from further consideration. A distance matrix was used to assign sites to clusters within 10 km of one another. Sites that were more than 10 km from any other site (i.e., not assigned to a cluster) were kept in the final list. In addition, at least one site was selected from each cluster. If there was an elevation span of more than 500 m within a cluster, two sites at either end of the elevation spectrum were chosen from the cluster. When the elevation span was less than 500 m, a single site was selected from each cluster based on georeferencing error and specificity of locality description. This process led to the selection of 62 historical sites to be surveyed in Colorado. Additional sites were surveyed in Wyoming and New Mexico by CU.

Historical Site Survey Protocol:

Prior to visiting a historical site on the ground, observers used aerial photos to evaluate habitat potential at the historical point and within the precision level of that point. Potential habitat included talus slopes adjacent to vegetation that could provide adequate nutrition for pika. Because pika are an obligate associate of talus habitat, this pre-survey narrowed the scope of survey efforts and helped observers locate potential habitat prior to field visitation.

In the field, observers hiked to the nearest potential talus habitat to the historical record. Once the observer reached a talus patch, they would begin to survey for pika. Pika are diurnal and have been found to be easily detected by both aural and visual surveys (Smith 1974). Surveys included listening for the distinct vocalizations of the pika, visually detecting an animal, looking for haystacks, and/or detecting urine/fecal stations to determine presence at a site. Observers were trained to identify fresh (< 1 year old) hay or scat by using cues such as a residual green tint and some flexibility/plasticity. Old (> 1 year old) hay or scat was assumed to be brittle and to lack any green coloration. If the first site surveyed was found to be unoccupied, other areas of appropriate talus habitat were searched within the spatial precision level of the site location until either a pika was detected, or until the entire area within the precision estimate was surveyed. A subset of historical sites was sampled on 2 occasions by separate observers to determine the probability of detecting a pika, and to help confirm any absences recorded.

Regardless if a pika was detected or not, sites surveyed were characterized using slope, aspect, potential disturbance, and vegetation characteristics. Slope was recorded at a site using a clinometer to measure the degree of the “fall line” of the slope through the site center. Aspect was determined with a compass standing at the site center recording the average aspect to the nearest 5 degrees. The estimated distance to the nearest road or jeep trail that could be used by vehicles as small as 4-wheelers (ATVs) was estimated as well as distance to the nearest hiking trail. If there was evidence of livestock grazing within 100 m of the talus slope that was also noted. Finally, the surrounding vegetation within 100 m of the historical site was characterized using the following classes:

AM	- <u>A</u> lpine/sub-alpine <u>M</u> eadow
AH	- <u>A</u> spen forest with <u>H</u> erbaceous understory
AEH	- <u>A</u> spen/ <u>E</u> vergreen forest with <u>H</u> erbaceous understory (>25% aspen)
AN	- <u>A</u> spen forest with little or <u>N</u> o herbaceous understory
EN	- <u>E</u> vergreen forest with <u>N</u> o understory
WS	- <u>W</u> illow <u>S</u> crubland
MM	- <u>M</u> ountain <u>M</u> ahogany scrubland
SS	- <u>S</u> age <u>S</u> crubland
WT	- <u>W</u> etland/pond/marsh/lake
O	- <u>O</u> ther

New Pika Site Surveys:

In addition to collecting information at known historical sites, data were also collected at undocumented sites. In a coordinated effort with the United States Forest Service (USFS), CDOW, and volunteers, data were collected in an opportunistic manner as agency biologists and volunteers conducted historical pika surveys or performed other work duties. Observers were asked to survey areas that looked appropriate for pika occupancy and characterize the site using a standard protocol and data sheet. New site locations were defined as those sites that represented a discrete population area and not simply an individual pika sighting. A discrete population area was defined as a talus patch separated by unsuitable habitat from another talus patch by a distance greater than the observer thought a pika would travel during daily foraging activities, or talus patches separated by a topographic feature such as a river, cliff or lake. Observers collected a UTM coordinate and documented projection at the talus site. If time allowed, individuals characterized the site using slope, aspect, and vegetation and recorded any type of disturbance within 100 m of the site.

Occupancy Sampling:

A pilot study investigating the use of occupancy sampling was completed in CDOW's Northeastern Region. The baseline data collected from surveys will help inform future monitoring efforts by supplying derived estimates of detection probabilities, and percent occupancy which can both be used to generate a monitoring program with sufficient precision for adequate management of the species.

Occupancy data was collected at 53 spatially-balanced (Theobald and Norman 2006) 200 m x 200 m plots. Plot location was stratified by elevation into 4 zones: 3201-3506 m (10,500-11,500 ft), 3506-3810 m (11,500-12,500 ft), 3810-4115 m (12,500-13,500 ft), and 4115 m and above

(13,500 ft plus). At each of the individual 53 plots, 2 cluster plots (200 m x 200 m) were also sampled within 100-200 m of each other, and of the primary plot. Cluster sampling was used to boost sample size and increase power to detect differences in proportion of plots occupied per elevation zone.

Occupancy surveys were conducted from 1 July until mid-September 2008. Sites were visited on 2 occasions to determine the probability of detection. Visual surveys occurred in the morning and ended by 11:00 am. Surveys were not conducted during precipitation events and when winds exceeded 15 mph.

Surveys of plots were completed with 1 person walking the perimeter of the 200 m plot looking for presence of pika, which included visual or auditory identification, scat stations, and fresh haypiles. Plot boundaries were located with GPS units that contained coordinates of the corner points of a plot.

Covariate data were collected within 4, 100 m quadrats within the 200 m plot (Figure 2). Dividing the plot into sections occurred because of the wide array of habitat types a 200 m plot could cover within mountainous terrain. In Colorado, high elevation habitats are known for being highly heterogeneous, thus a single 200 m plot could encompass talus/boulder on one section, a willow carr in another section, and meadow in another. Covariates collected in each quadrat included the following cover classes: talus/boulder, cliff/rock outcrop, thin forest, scattered rock/boulder, dense forest, willow, and alpine/subalpine meadow. Slope and aspect within a plot were not collected in the field, but were documented using Geographic Information Systems (GIS) software (ArcGISv9).

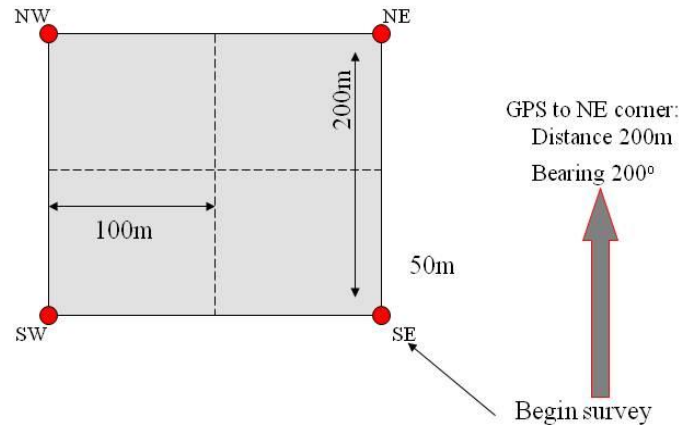


Figure 2.0. Diagram of the “transect” walked by observer during occupancy surveys conducted on randomly selected 200m x 200m plots.

Predicted Range Model:

A Predicted Range Model was developed from data collected during historical, new site, and occupancy sampling surveys (Figure 3). This model was used for the assessment of potential habitat and connectivity of populations, to investigate potential threats to the species, and for site selection in future monitoring efforts.

The model was developed by extracting zonal attributes of elevation, slope, aspect, and SWReGAP vegetation classes for each point and attributed the value. For the points falling in Alpine Fell Field, Alpine Scree, Cliff & Canyon (Prime Classes), a ½ km buffer was used to find and assign the majority vegetation value within that buffer. Next, histograms for elevation, slope, and vegetation classes were generated for site variables to facilitate analysis/review of site use patterns. Field data collected on the same parameters were used to validate the model.

For the histogram/pattern overview analysis, the following coding/weighting classes were developed:

Elevation (derived 30 m USGS DEM):

Class	Data Range (ft)	(m)	Ranking
1	9-10,000	2743-3048	5
2	10-11,000	3049-3352	3
3	11-12,000	3353-3658	1
4	12-13,000	3659-3963	2
5	13-14,000	3964-4267	4
6	14-14,433	4268-4399	6

Slope (derived from 30 m USGS DEM):

Class	Data Range (Pct)	Ranking
10	0-10	3
20	10-20	1
30	20-30	2
40	30-45	4
50	45+	5

Vegetation Classes (derived from SWReGAP Land Cover dataset):

Class	Veg. Class	Ranking
100	Dry Spruce Fir Forest and Woodland	4
200	Spruce Fir Forest and Woodland	2
300	Montane Subalpine Grassland	8
400	Subalpine-Montane Riparian Shrubland	3
500	Aspen Forest and Woodland	7
600	Alpine Montane Wet Meadow	6
700	Dry Tundra	1
800	Subalpine Mesic Meadow	5

Elevation, slope, and vegetation variables were re-coded from original datasets to GRID format with the above class values. GRIDs were combined using an additive function giving ‘trace-back’ function for each cell.

Site selection will be performed using this model by stratifying areas that meet the first through eighth ranking criteria.

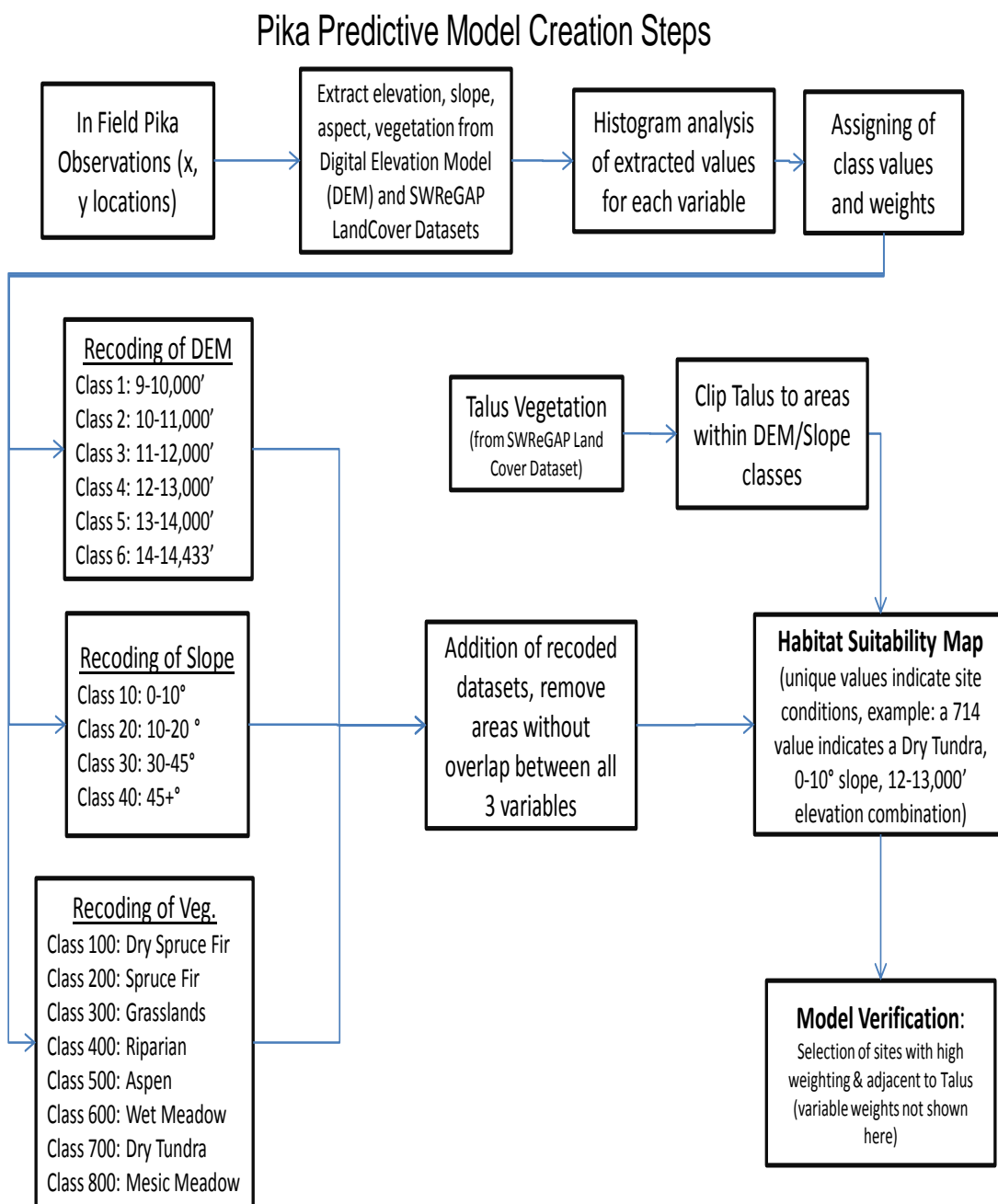


Figure 3. Process steps used to create the Predicted Range Model for Pika in Colorado based on 2008 survey information.

Results

Historical Sites:

Sixty-two historical sites were surveyed to determine occupancy of pika in 2008. Of the 62 historical sites surveyed, 58 were found to be occupied (93.5% occupancy) and 4 were found to be unoccupied (6.5%; Figure 4). Of the unoccupied sites, 2 contained suitable talus habitat for pika, but only one of the sites contained sign of past pika occupancy (old scat and haystacks). The other 2 unoccupied sites lacked talus habitat and overall appeared unsuitable for pika occupation. The unoccupied sites ranged in elevation from 2621 – 3343 m (8600-10,965 ft). The lowest elevation historical site that was occupied by pika was 2745 m (9005 ft). This currently occupied historical site expands the lower extent of the range of the pika as described in the Mammals of Colorado (Fitzgerald et al. 1994) which states pika are found at or above 3000 m (10,000 ft).

Of the 62 historic sites that were sampled, 6 had evidence of domestic livestock grazing (<10%) within 100 m of the site. Only one of the 6 sites that had evidence of domestic livestock grazing was currently unoccupied by pika. Twenty-seven of the 62 historical sites (44%) had a hiking or jeep trail within 100 m of the site. One of the unoccupied sites had a trail within 100 m of the site while the other three unoccupied sites had no evidence of trails within 100 m.

New Pika Sites:

One hundred and sixty-six undocumented discrete pika population sites were identified in 2008. These sites were well distributed across the state (Figure 4).

During occupancy sampling in the Northeastern CDOW Region, observers recorded points of individual pika locations rather than actual discrete population areas as was recorded in the rest of the state. To make these individual animal data points fit the statewide protocol for recording discrete population locations, a ½ km buffer was mapped around each individual pika sighting using GIS, and only sightings within non-overlapping buffers were considered as separate populations.

The number of recorded individual pika sightings was 291. Using the GIS buffering, these 291 individual sightings resulted in 53 new discrete population sites. Thus with the original 166 documented sites and the 53 sites recorded during occupancy sampling, a total of 219 discrete population sites were identified in 2008.

Occupancy Sampling:

One hundred and fifty-seven plots were sampled within the 4 elevation zones. Seventy-nine of these plots were occupied by pika resulting in an occupancy rate of 53%. Of the 53 primary plots, 26 were occupied. The proportion of occupied plots varied by elevation probably due to the fact that more suitable habitat is available for pika at elevations between 3353 m and 3963 m (11,000-13,000 ft). The proportion of occupied plots per elevation zone was: 3201-3506 m (10,500-11,500 ft) = 16.7% (SE=0.062), 3506-3810 m (11,500-12,500 ft) = 43.7% (SE=0.079),

3810-4115 m (12,500-13,500 ft) 89.5% (SE=0.051), and 3810 m and above (13,500 ft plus) = 59.2% (SE=0.0790 (Table 1).

The probability of detection for pika was 0.93. The habitat variable with best support as a predictor of pika presence was presence of talus or boulder fields (Table 2).

Predicted Range Model:

Data used to develop the Predicted Range Model included the 58 occupied historical sites, the 219 previously undocumented sites, and the 26 primary plots that were found to be occupied during occupancy surveys. The cluster plots were not used in development of the Predicted Range Model because they were not spatially independent from the primary plot and thus, may not have represented a discrete population area.

Using this combination of datasets, the number of discrete sites located statewide that contained pika was 303. The range in elevation of these sites was 2745-4294 m (9,005-14,087 ft; Figure 5) with the majority of sites (36.3%) occurring between 3353-3658 m (11,000-12,000 ft;). Slopes measured at pika occurrence sites ranged from 0-60° with a majority of sites (32.6%) occurring on relatively low angle slopes (10-20°; Figure 6). Aspect at sites ranged from 1- 360°.

One hundred and twenty-seven pika sites (42%) were found to occur within the Alpine Fell Field, Alpine Scree, Cliff & Canyon SWReGAP Vegetation Classes. The SWReGAP Vegetation Classes found at all sites included Aspen, Subalpine dry spruce fir, subalpine wet spruce fir, Lodgepole pine, montane mixed conifer, Gambel Oak mixed shrub land, subalpine meadow, subalpine grassland, subalpine riparian, subalpine and wet meadow. Dry tundra represented the dominant vegetation class at sites (35%; Figure 7).

The Predicted Range Model estimated 3,623,146 ha (8,952,991 ac) of potential pika habitat within Colorado; 13.4% of the state (Figure 8). This estimate included all talus and surrounding SWReGAP vegetation classes located in the ½ km buffer within the defined slope and elevation ranges. Paring down the model to include only the SWReGAP vegetation classes of Alpine Fell Field, Alpine Scree, Cliff & Canyon and excluding all other vegetation classes, the model predicted 404,411 ha (999,286 ac) of potential pika habitat in the state; 1.4% of the state.

Landownership in the predicted range model was predominantly USFS lands (60.4% in model and 77% in talus areas; Table 3) with wilderness areas comprising 23.6% of the area in the model and 4.8% in talus areas. Private lands comprised 8.3% of the model and 7.4% of talus areas. Two hundred and eighty-three pika occurrence points were located on public lands; 106 of these sites occurred in wilderness areas. Only 20 pika occurrence points were located on private lands.

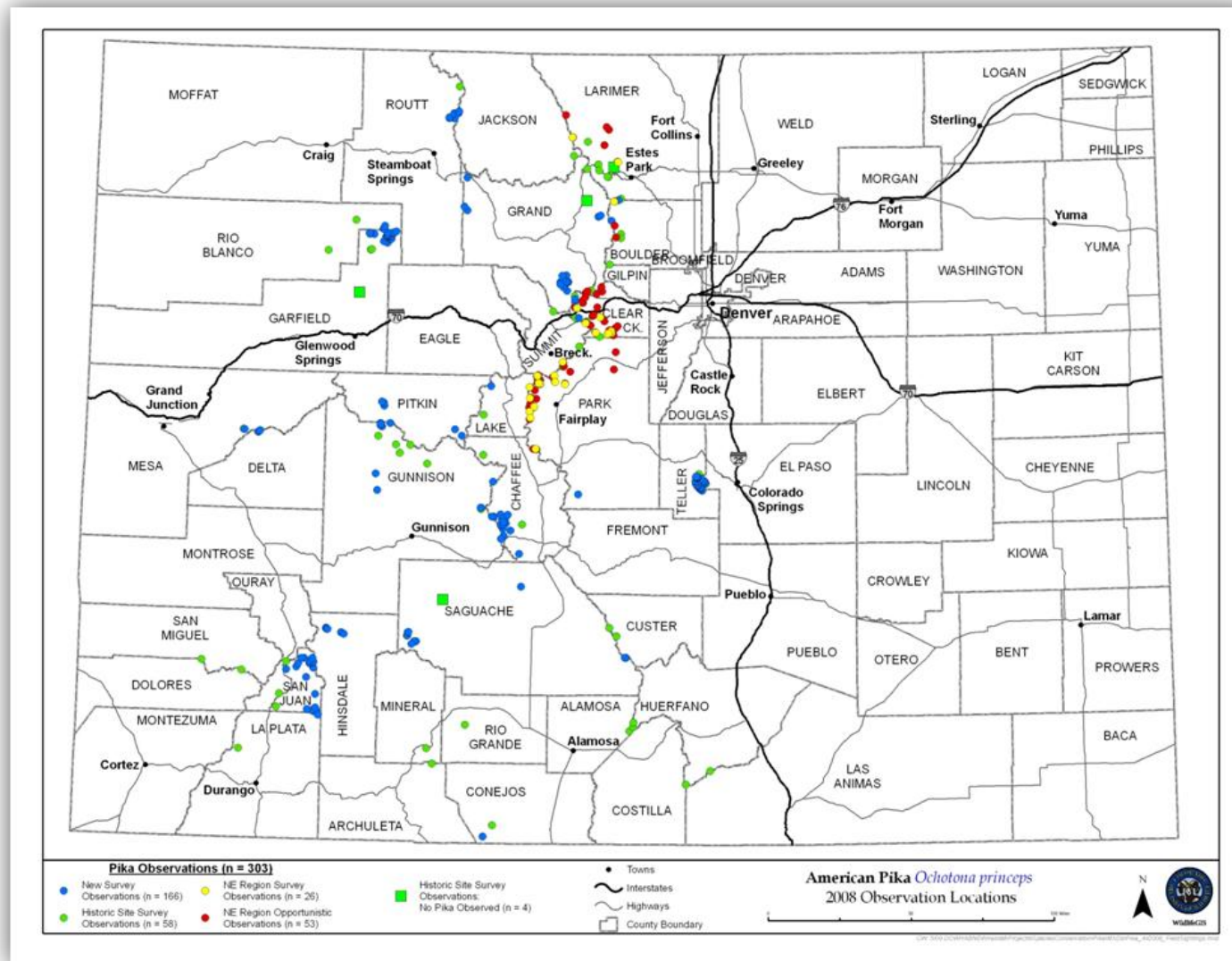


Figure 4. Pika 2008 occurrence data from historical, opportunistic, and occupancy surveys.

Table 1. Pika occupancy rates by elevation zones in the CDOW Northeastern Region of Colorado.

Elevation Zone	Elevation Range (m)	Occupancy	SE	95% Lower CI	95% Upper CI
1	3201 - 3506	0.167	0.062	0.077	0.325
2	3506 - 3810	0.437	0.079	0.292	0.595
3	3810 - 4115	0.895	0.051	0.745	0.962
4	4115 - plus	0.592	0.079	0.433	0.734

Table 2. Pika covariate model for occupancy in the CDOW Northeastern Region of Colorado.

Covariate	AICc	Δ AICc	Wi
Talus/boulder	230.03	0.00	0.412
Elevation	248.304	18.27	0.000
Willow	286.056	56.02	0.000
Cliff/rock outcrop	286.423	56.39	0.000
Alpine/subalpine	287.791	57.76	0.000
Scattered rock boulder	287.791	57.76	0.000

Table 3. Landownership estimates in the Predicted Range Model.

Pika Predicted Range Model		
OWNER	(Ha)	Talus Areas (Ha)
USFS	1,879,439	311,735
BLM	122,991	18,183
State Lands	31,389	2348
Private	272,952	29,911
NPS	58,987	21,071
Federal	10	56
Other	1708	1301
Wilderness	836,531	19,802
Totals:	3,218,745	404,411

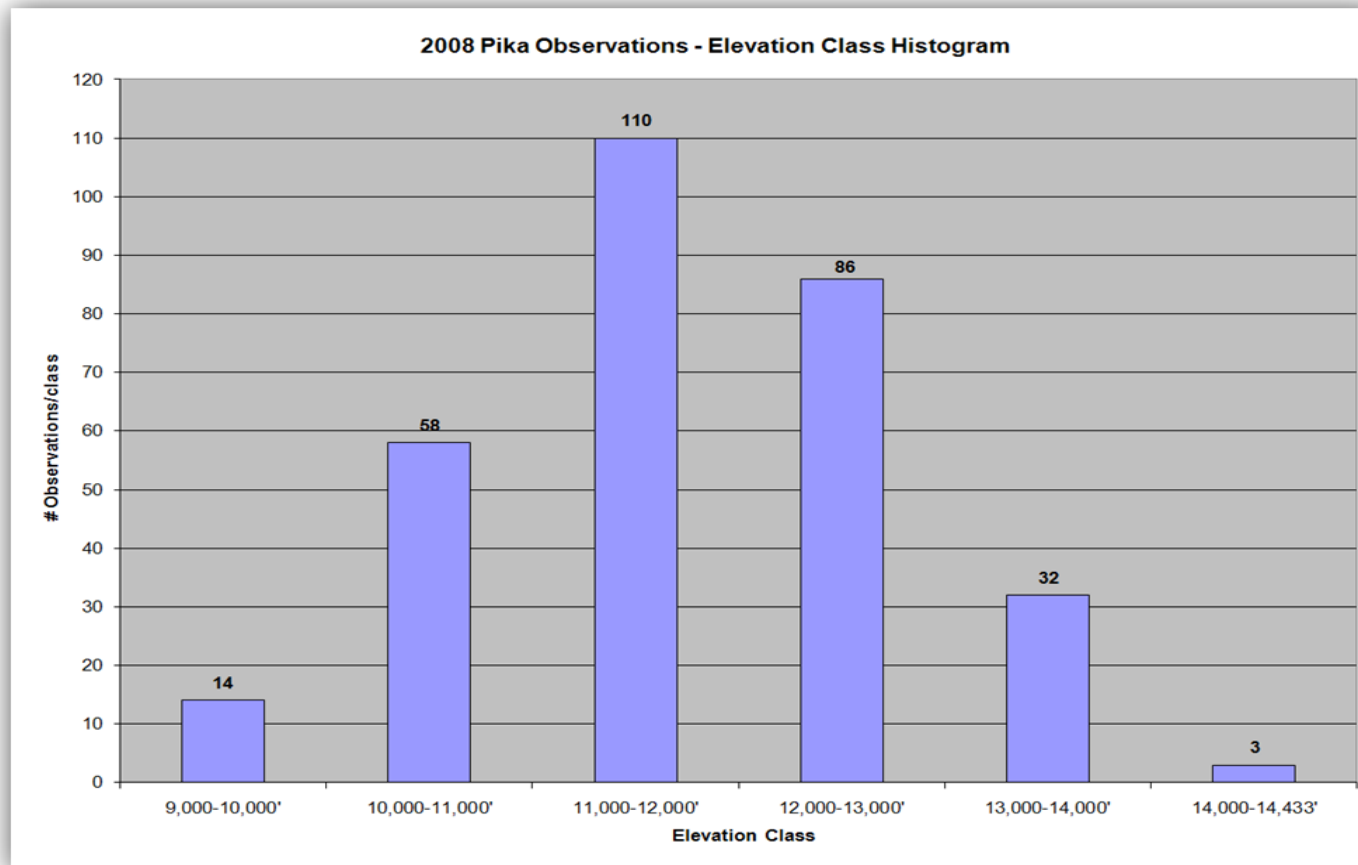


Figure 5. Elevation classes for 303 pika occurrence data points collected in 2008.

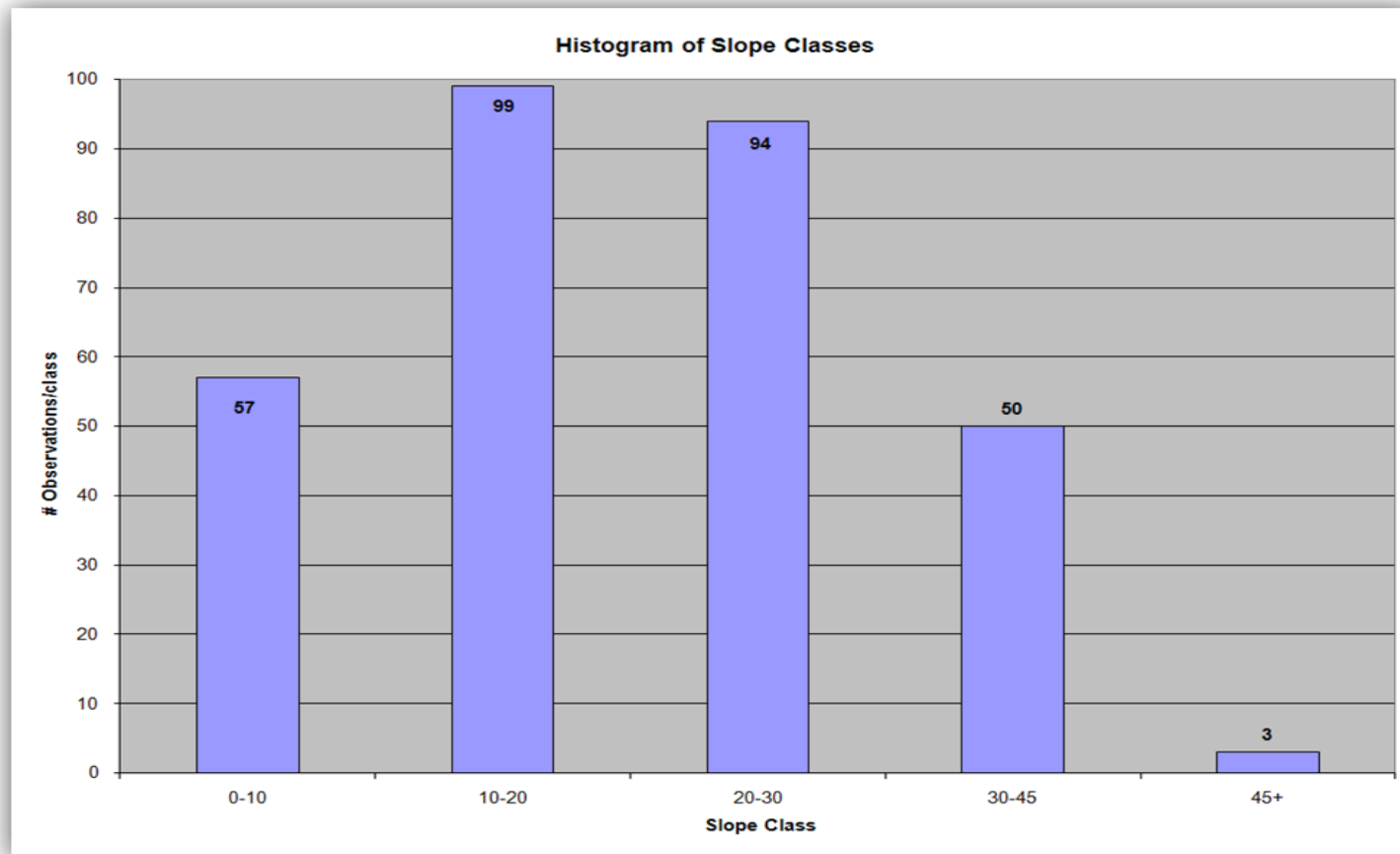


Figure 6. Slope classes for 303 pika occurrence data points collected in 2008.

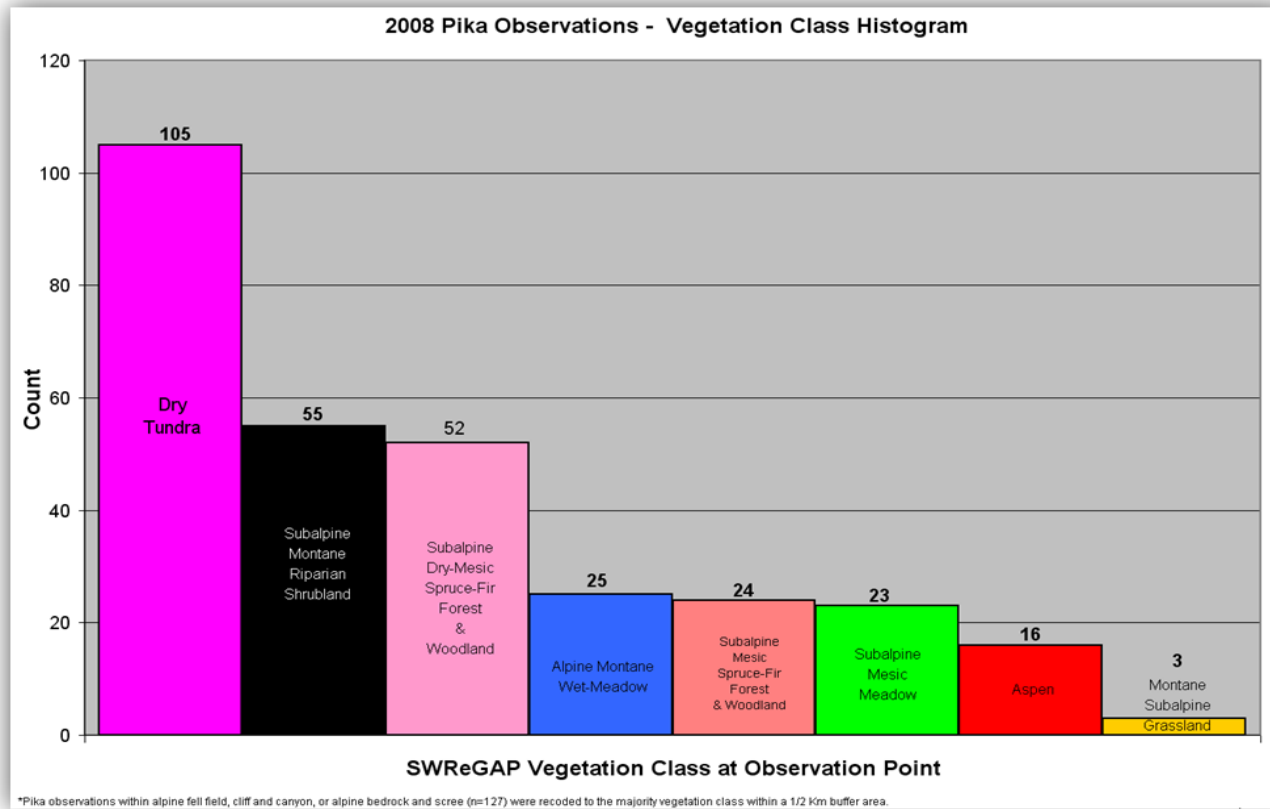


Figure 7. SWReGAP vegetation classes recorded for 303 pika occupied sites surveyed in 2008. For the points falling in Alpine Fell Field, Alpine Scree, Cliff & Canyon (Prime Classes, n=127), a 1/2 km buffer was used to find and assign the majority vegetation value within that 1/2 km buffer.

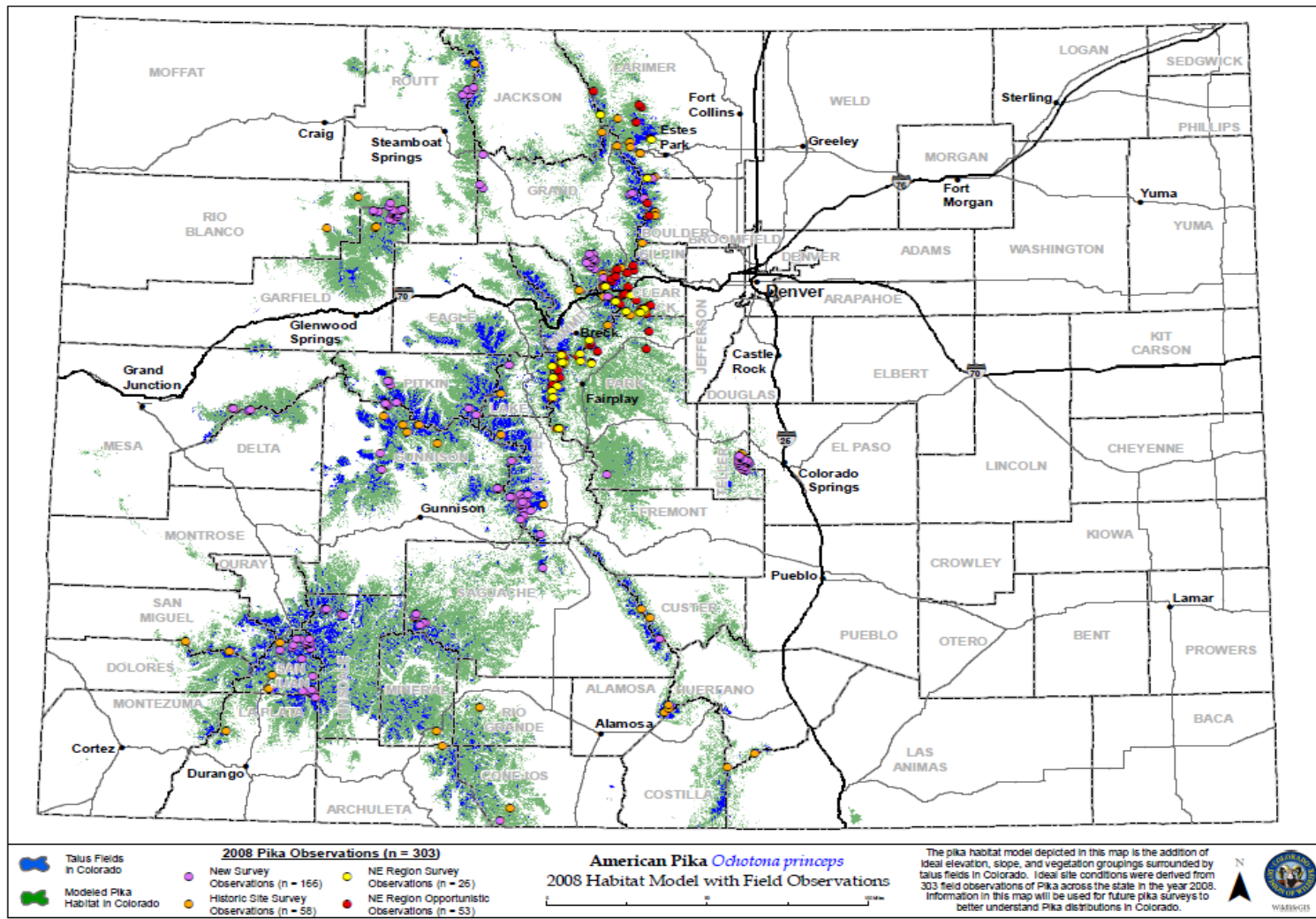


Figure 8. Predicted Range of the pika in Colorado based on vegetation class, slope, and elevation. Field data for development of the model was based on 303 discrete population areas of pika recorded in 2008.

Discussion

The concern identified in the petition to list the pika under the ESA was predominantly based on population data from the Great Basin documenting extirpations of pika populations at low elevation sites (Beever et al. 2003; Center for Biological Diversity 2007). Other examples presented in the petition, included the Grinnel Resurvey Project in the Sierra Nevada Mountains of Yosemite National Park (Moritz 2007) where pika were found to have contracted their range upward by 152 m (500 ft), and from a research project at Bodie, California where it appeared that successful colonization decreased with progressively lower elevations, until colonization could not offset extinction rates (Smith 1974). Though these studies identify issues that may impact pika population persistence due to climate change and anthropogenic disturbances, it should be noted that several of the study locations (Smith 1974; Beever et al. 2003) occurred in environmentally marginal pika habitat where extinctions may be more likely. Conversely, within other areas of the Central Sierra Nevada Mountains, California and adjacent southwestern Great Basin Ranges in California and Nevada, Millar et al. (2008) documented abundant pika occupied sites ranging in elevation from 1827 m (5992 ft) to 3768 m (12,359 ft) which the authors noted represented a broader distribution of pika in these areas than was previously thought to occur. The authors also described the widespread abundance of pika documented in their studies to be more reminiscent of early 20th century pika population estimates rather than a trend toward extirpation. For example, elevations recorded were lower than recent or historic literature for this area. Because ecoregions differ markedly throughout the range of the pika with respect to weather patterns, elevation, and availability of habitat, extrapolation of results from limited areas may not represent what is occurring throughout the range of the pika.

From the developed Predicted Range Model, it was estimated that Colorado contains approximately 3,623,146 ha of potential pika habitat in the state (13.4% of the state). This habitat extends from elevations as low as 2743 m (9000 ft) to over 4628 m (14,000 ft). Examining the map produced from Hafner (1994; Figure 1), our Predictive Range Model mirrors what was estimated to be the distribution of pika in Colorado based on elevation and vegetative zones. In comparison, Hafner's map showed very little contiguous habitat occurring in the Great Basin areas in Nevada and Southeastern Oregon where Beever et al. (2003) conducted research. Isolated patches of talus in the Great Basin may result in pika populations being more prone to extinction due to climate warming and stochastic events because of the low vagility and philopatric nature of the species (Hafner and Sullivan 1995). Hafner (1994) concluded that populations of pika occurring within altithermal refugia >100 km² had higher survivorship than those within smaller refugia. The 2008 survey data indicated pika populations are abundant and well distributed throughout the state. The Predicted Range Model also provided evidence of extensive and largely contiguous suitable pika habitat, suggesting that Colorado pika populations should have patch size and connectivity to maintain a metapopulation structure sufficient to preserve populations.

Colorado during the last 50 years, not unlike the Great Basin and Sierra Nevada Mountains, has experienced rising temperatures and increased precipitation (National Conference of State Legislatures 2008). Overall, the state has warmed more rapidly than the U.S. average, with the most notable temperature increases at higher elevations (National Conference of State Legislatures 2008). If climate change continues along the same trajectory during the next 100

years, high elevation areas in Colorado will likely see winter and summer temperatures increase by 5° F to 6° F along with 20-70% increases in precipitation (National Conference of State Legislatures 2008). Though precipitation is expected to increase, less of this precipitation will fall as snow (IPCC 2007). These changes in climate at high elevations can mean less snow cover in the winter, earlier snow melt in spring and significantly warmer summers that could all impact pika foraging rates and increase thermal stress on the animals. Though climate change is and will continue to impact the Southern Rocky Mountains in Colorado, it is expected that the most vulnerable places are at lower elevations where the climate is temperate and little alpine habitat exists (Krajick 2004). The majority of pika detections in Colorado occurred in the elevation range of 3353 to 3658 m (11,000 to 13,000 ft). At these elevations in Colorado, there is abundant alpine and subalpine habitat that may serve as a stronghold for the species as impacts from global climate change continue.

Recent work examining potential impacts on pika due to climate change found that extremely cold temperatures during winter and higher average temperatures during summer explained population extirpations—patterns that suggest effects of acute cold stress and chronic heat stress (Beever et al. *in press*). Hafner (1991) found that pika occur in regions where there are < 30 days/year when temperatures reach above 35°C. In the Southern Rocky Mountains in Colorado average annual temperatures range from 1.7°C to 7.2°C and rarely reach above 28°C in even the hottest months. Hafner (1991) also found that pika occur in regions that receive >200 mm of annual precipitation. The Southern Rocky Mountains produces moist weather patterns due to monsoons during the summer and high snowfall totals in the winter. Winter precipitation varies considerably depending on elevation with the highest elevations in Colorado receiving most of their precipitation in the form of snow. Overall, average annual precipitation in the Southern Rocky Mountains is estimated to be 360 mm. Thus though the climate may be changing in the Southern Rocky Mountains, it currently appears that climate conditions in the state fall into the realm of appropriate temperature and precipitation cycles appropriate for maintaining healthy pika populations and distribution.

In addition to effects of talus patch size, climate change, and elevation, anthropogenic disturbances have been found to play a potential role in pika extirpations (Beever et al. 2003). Beever et al. (2003) found that population persistence correlated negatively with distance from primary roads indicating disturbance due to road access could have an impact populations and extinction potential. The measured degree of human disturbance recorded at pika sites in Colorado was relatively minimal and did not appear to account for absences recorded at historical sites. Most disturbances recorded were hiking and/or ATV trails within 100 m of a site. However, the degree at which these trails were utilized was not measured. Secondary roads as measured by surveys may result in less of an impact on pika populations, and hiking trails may result in even less of a disturbance. Anthropogenic disturbance on pika in Colorado may be limited since a large portion of suitable habitat occurs in remote areas of public lands.

Very few of the historical sites surveyed in Colorado were impacted by grazing (<10%), although domestic livestock grazing was negatively correlated with pika population persistence in the Great Basin (Beever et al. 2003). Grazing impacts are mostly likely magnified in arid areas of the Great Basin (Hafner and Sullivan 1995) due to less vegetation being available for species and the increased potential for introduction of weeds. Grazing impacts may be minimal

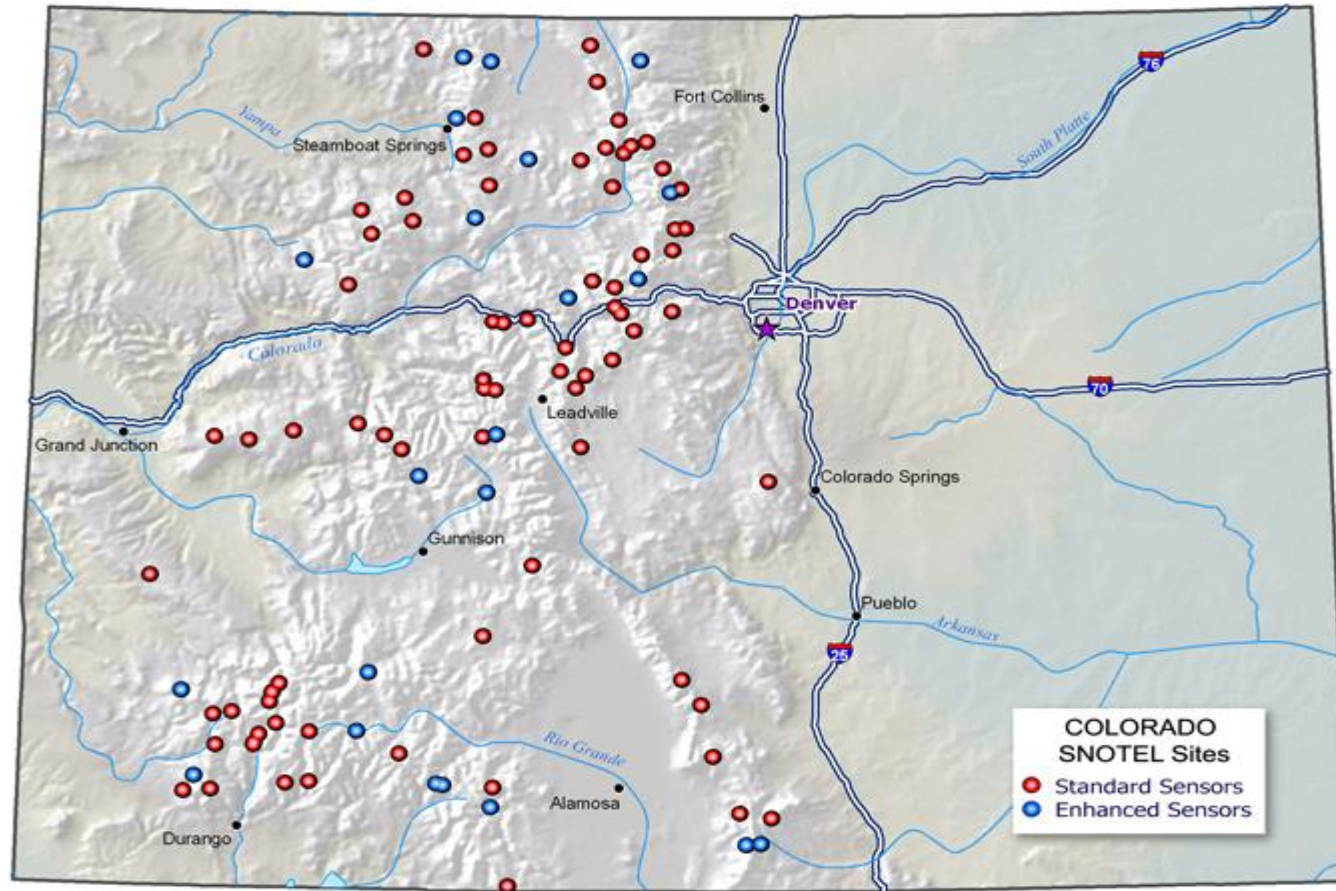
in Colorado since high elevation sites in the state are moister and have higher precipitation rates as compared to areas in the arid Great Basin. In addition, most pika occurrence sites are at elevations where grazing is less common.

The 2008 surveys indicate that pika are well distributed in Colorado's high country. The majority of historical sites (93.5%) surveyed had pika populations persisting throughout the state, even at low elevation sites. Pika habitat is extensive in the state and connectivity between talus patches and population areas may be sufficient to maintain a healthy metapopulation structure to allow populations to persist despite some local declines or extirpations. Anthropogenic disturbances seem to be limited and much of the available pika habitat occurs on public lands and in wilderness areas. At this time, it does not appear that pika populations in Colorado need the protection of the ESA, but CDOW needs to continue to monitor pika populations and develop a better understanding of how climate change may impact persistence of populations. Below are recommendations for continuing pika work in the state.

Recommendations

Since baseline information has been collected, the next step is to develop a long-term monitoring program that can monitor population changes and distribution. This effort will allow CDOW to correlate changes in climate with changes in the distributions of pikas, vegetation, and thermal stress parameters. To accomplish these tasks we recommend the following:

1. Site selection for monitoring - Sites to be sampled will be stratified using the developed Predicted Range Model to rank suitability of a site for pika occupancy. For example, sites in the prime elevation zone, vegetation class, and slope will receive a different ranking for monitoring than those at lower elevations, with steeper slopes, and less suitable vegetation classes.
2. Sites will be monitored within an occupancy modeling approach - As shown by the occupancy surveys in the Northeastern Region, pika have a high probability of detection and are obligates of talus habitat. They are also locally abundant and should produce high occupancy rates in suitable habitat. This long-term monitoring information will be useful for CDOW to evaluate distributional changes and how changes correlate with elevation, latitude, and measured covariates.
3. Distance sampling – Distance sampling will be incorporated at a subset of sites used for occupancy modeling (Hedley and Buckland 2004). The utility of density estimates is that they can be related to topographical, environmental, habitat, and other spatial variables in addition to enabling estimation of abundance for any subsite of interest within a surveyed area (Hedley and Buckland 2004). This information will not only improve the overall monitoring effort, but can provide information about the underlying ecological processes driving changes in distribution and abundance (Kissling et al. 2007).
4. Climate and vegetation data - Vegetative changes will be monitored and temperature data loggers will be placed in talus in the vicinity of haypiles at a subset of sites to monitor the microclimate. Snowtel sites (Figure 8) will be used to extrapolate regional precipitation and temperature information to correlate with occupancy rate, densities, and vegetative changes.



Standard sensors include snow water equivalent, precipitation and temperature. Enhanced sensors may include any or all of following: soil moisture, soil temperature, wind speed/direction, solar radiation, humidity, precipitation (tipping bucket rain gage), or barometric pressure.

Figure 8. Location of Snotel sites in Colorado.

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